Activity 3

Superbugs: An Evolving Concern

At a Glance

Focus: Students investigate the growth of bacteria in the presence of antibiotics and use the results to explain a case of antibiotic-resistant tuberculosis.

Major Concepts: The re-emergence of some diseases can be explained by evolution of the infectious agent (for example, mutations in bacterial genes that confer resistance to antibiotics used to treat the diseases).

Objectives: After completing this activity, students will

- be able to explain how antibiotic treatment results in populations of bacteria that are largely resistant to the antibiotic and
- describe inappropriate and / or questionable uses of antibiotics.

Prerequisite Knowledge: Students should be familiar with bacterial growth and with evolution by natural selection.

Basic Science-Public Health Connection: In this activity, students learn that the evolution of antibiotic resistance among bacteria observed in laboratory experiments occurs in the natural environment as well, and that such evolution has serious consequences for the effectiveness of treatments for some diseases.

Introduction

In 1943, penicillin was introduced as the "magic bullet" for curing many infectious diseases. By 1946, however, approximately 14 percent of *Staphylococcus aureus* strains isolated at a London hospital were resistant to penicillin. Today, scientists estimate that more than 95 percent of all *S. aureus* strains are penicillin-resistant.

After the introduction of penicillin, additional antibiotics were rapidly isolated and developed, including streptomycin and the tetracylines. Today, there are more than 100 antibiotics available. Nevertheless, some strains of at least three bacterial species (*Enterococcus faecium*, *Mycobacterium tuberculosis*, *Pseudomonas aeruginosa*) are resistant to all of these antibiotics, and health care workers fear the time is rapidly approaching when more deadly organisms escape the effects of all known antibiotics.

The primary reason for the increase in antibiotic resistance is evolution. When mutant genes arise that make a bacterium less sensitive to an antibiotic, that bacterium survives and produces descendants in an environment rich in antibiotics. That is, the process of natural selection operates. Multiple mutations may be required to result in fully resistant bacteria. However, once resistant genes appear, bacteria have a variety of mechanisms for exchanging those (and other) genes both within and across species. These mechanisms include conjugation,

transformation, transduction, and transposon-mediated exchange. This exchange allows for "accelerated evolution" of bacterial species (accelerated in the sense that random mutations that result in antibiotic resistance need not occur in every individual bacterium, nor even in every species of pathogen, but can simply be acquired from another organism).

This activity invites students to explore one reason for the re-emergence of some infectious diseases: the evolution of antibiotic resistance among pathogens. In Activity 4, *Protecting the Herd*, students explore another reason for the re-emergence of infectious diseases.

Materials and Preparation

You will need to prepare the following materials before conducting this activity:

- Master 3.1, *Bacterial Growth Experiment* (make 1 copy per student)
- Master 3.2, *Discussion Questions for the Bacterial Growth Experiment* (make 1 copy per student)
- Master 3.3, *Debi's Story* (make 1 copy per student)
- Master 3.4, *Debi's Story: Explaining What Happened* (make 1 copy per student)
- Master 3.5, *Antibiotic Concerns* (make 1 per team)

Students complete this activity across a five-to-seven day period. You will need to prepare the materials for the laboratory exercise. Ordering information and preparation directions are on page 9, immediately following the activity.

Information about the safe use of microorganisms in classrooms, including lists of organisms considered safe for students at various levels of school, can be found at: http://www.science-projects.com/safemicrobes.htm. A number of leaders in infectious diseases, including scientists from NIH, contributed to the Web site. *Pseudomonas fluorescens*, the organism used in the laboratory exercise in this activity, is included on the list of microorganisms considered appropriate for students in grades 9 or higher. Nevertheless, experts acknowledge that people who are immunocompromised may be at risk for infection by organisms that do not affect healthy individuals. We recommend that you read a statement such as the following to your classes before beginning the activity:

> *Pseudomonas fluorescens*, the bacteria used in the laboratory exercise you will begin soon, does not cause disease in healthy people. However, people who have weakened immune systems should not have contact with most microorganisms or with people who handle those organisms. Your immune system may be weakened if you are undergoing antibiotic therapy, if you are taking immunosuppressive drugs or drugs for cancer treatment, or if you have AIDS or are HIV-positive. If you have a weakened immune system for these or any other reasons, let me know and I will provide you with an alternative experience that is safer for you.

Procedure

DAY 1 (5 to 7 days before Day 3 of the activity)

1. **Remind students of the theory of evolution by natural selection and tell them that a powerful feature of theories is that they lead to hypotheses that can be experimentally tested.**

   Students should be able to state the basic elements of the theory of evolution: (1) there is variation among the individuals in a population; (2) some of these differences can be inherited; (3) some individuals will be better adapted to their environment than others; (4) the better adapted individuals will reproduce more successfully; and (5) thus, the heritable characteristics that make individuals better adapted will increase in frequency in the population.

2. **Organize students into teams of three and challenge the teams to use their understanding of evolution by natural selection to write a hypothesis about what will happen in a population of bacteria after growing for several generations in the presence of an antibiotic.**

   If students have difficulty with this, stimulate their thinking by asking questions such as, "What effect does an antibiotic usually have on a bacteria? Do you know of cases in which that effect did not occur? What does that suggest about variations that exist in the bacteria population? Which bacteria survived? What trait did they pass on to other progeny?"

3. **Convene a class discussion in which you ask several teams to share the hypotheses they developed. Challenge the class to work together to refine them into one hypothesis similar to the following:**

   If a bacterial culture is grown in a medium containing an antibiotic, then after several generations, all of the bacteria in the culture will be resistant to the antibiotic.

4. **Tell students that they will conduct an experiment to test this hypothesis and explain that they will also consider the implications of their results for controlling infectious diseases in an activity the following week. Then distribute Master 3.1, *Bacterial Growth Experiment*, and instruct students to complete Steps 1 through 4 with their team members.**

   Emphasize that for safety reasons as well as the success of their experiments, students must use aseptic techniques. If students are not familiar with aseptic techniques for handling bacterial cultures, you will need to demonstrate them.

DAY 2 (2 to 3 days before Day 3 of the activity)

1. **Direct teams to complete the remaining steps on *Bacterial Growth Experiment*.**

DAY 3

1. **Tell students that today they will analyze the results of the bacterial growth experiment they have been running and will use those results to help explain what happened to a high school student who had tuberculosis.**

2. **Organize students into teams and instruct them to collect their bacterial growth plates. While they do this, distribute a copy of Master 3.2, *Discussion Questions for the Bacterial Growth Experiment*, to each student. Tell the teams to draw (or describe) their results on the flow chart on *Bacterial Growth Experiment* first, then refer to those results as they discuss and write answers to the discussion questions.**

   Depending on students' microbiology background, you may need to explain that when a single, microscopic bacterium is placed on an agar plate, it will grow and divide into two progeny cells. Each progeny cell will grow and divide, and so on, until thousands and thousands of individual bacteria are growing right in that spot. At this point, the growth becomes visible to us as a colony of bacteria. Each colony came from a single original bacterium on the plate. When approximately 10,000 or more bacteria are plated, each individual bacterium is close enough to a neighboring bacterium that the colonies they produce merge together, and we observe confluent growth or a "lawn" of bacteria across the plate.

   Move among the teams as they discuss each question and help lead students to the following understandings.

   Question 1 Compare the bacterial growth on the two plates from the parental culture (Plates 1 and 2). Which has more growth? Explain why. How do you explain the presence of bacteria on the plate containing kanamycin?

   The nutrient agar plate (Plate 1) should show a lawn of bacteria or confluent growth, whereas the plate containing kanamycin should show only 50 to 100 colonies. Students should explain that the antibiotic prevented the growth of most of the bacteria on Plate 2. A simple, straightforward answer is all students need to provide for the last question: The bacteria that grew on Plate 2 were resistant to the antibiotic.

   Question 2 Compare the growth on Plates 3 and 4 , which you prepared from culture A (without kanamycin). How does the growth on the plates with and without kanamycin appear? What does this tell you about the bacteria grown in culture A?

   The plate without kanamycin (Plate 3) should show a lawn of bacterial growth, whereas the plate with kanamycin (Plate 4) should show 50 to 100 colonies. The results on Plate 3 indicate that a lot of bacteria were growing in the sample plated from culture A. Comparing the results on that plate with the results on Plate 4 indicates that some of

the bacteria in the culture (for example, 50 out of 10,000 or more) were resistant to the antibiotic, but most were not.

Question 3 Compare the growth on Plates 5 and 6, which you prepared from culture B (with kanamycin). How does the growth on the plates with and without kanamycin appear? What does this tell you about the bacteria grown in culture B?

Both plates should show a lawn of bacterial growth. This indicates that most or all of the bacteria growing in this culture were resistant to kanamycin.

Question 4 Compare the growth of cultures A and B on Plates 4 and 6 (with kanamycin). Explain how culture B could have so many more resistant bacteria than culture A, even though they both came from the same parental culture.

If, after a minute or two of discussion, students cannot offer an explanation, suggest that they use their understanding of natural selection to explain the difference in the results on the plates for the two cultures. They should be able to explain that the environment in culture B (which contained kanamycin) *selected for* the growth of those bacteria that were resistant to kanamycin. By the time students plated a sample from that culture, all of the bacteria in the sample were resistant, so they all grew on the plate with kanamycin, resulting in a lawn of bacterial growth (Plate 6). Culture A did not contain kanamycin, so there was no selection for kanamycin resistance, and most of the bacteria they plated from that culture were not resistant. Thus, most did not grow on the plate with kanamycin (Plate 4).

Question 5 How do you explain the presence of some resistant bacteria in the parental culture and culture A?

To answer this question, students must recognize that bacteria become resistant (for example, through mutation) *before* natural selection operates. In other words, the bacteria in the parental strain did not "know" that some of them would be placed in growth medium with kanamycin and "respond" by becoming resistant. Instead, in the parental strain, a few bacteria were already present that were resistant to kanamycin, even though there was no kanamycin present. Similarly, a few bacteria in culture A were resistant to kanamycin even though no antibiotic was present. When the resistant and nonresistant bacteria from the parental culture were placed in medium containing kanamycin (culture B), only the resistant bacteria survived and reproduced, passing their kanamycin resistance trait on to their progeny. Soon, virtually all of the bacteria in the culture—the progeny of the original resistant bacteria—were resistant to kanamycin, as observed on the students' plates.

3. **Convene a brief class discussion in which you clarify any confusion you noted as you circulated among the groups and/or invite students to ask questions about the results of their experiments.**

4. **Tell students that they will learn about a young woman named Debi French and her battle with tuberculosis. Then they will use the results of their bacterial growth experiments to help explain what happened in her struggle with the disease.**

   Emphasize that the bacteria in their experiment (*P. fluorescens*) is not the kind that causes tuberculosis (*M. tuberculosis*). *P. fluorescens* does not cause disease in healthy people. Furthermore, the antibiotic kanamycin is not used clinically, so the resistant bacteria cultured in this exercise do not compromise medical treatments. Emphasize, however, that all bacterial cultures in your class are decontaminated before disposal and that aseptic conditions must be followed in all work with microorganisms.

As they use the results of their bacterial growth experiment to explain what happened to Debi French, students will experience how basic research leads to explanations for disease and for the success or failure of disease treatment. This understanding leads scientists to propose further research and policies directed at improving public health.

5. **Distribute one copy each of Masters 3.3, *Debi's Story*, and 3.4, *Debi's Story: Explaining What Happened*. Indicate that students have 20 minutes to read about Debi and answer the questions on *Debi's Story*.**

   You may want to emphasize to students that this is a true story.

   You may need to remind students of the information they learned about tuberculosis in Activity 1.

6. **Convene a whole-class discussion in which you ask several teams to share their responses to the questions on *Debi's Story*. Invite the other teams to add information and disagree with these responses. Then ask students, "What does the Debi French example suggest is an explanation for the re-emergence of diseases like tuberculosis?"**

   Students should be able to provide answers such as the following:

   Question 1

   - **Debi contracted tuberculosis (TB) from** a student in one of her classes who had an active, misdiagnosed case of TB. Debi did not know this student.
   - **The symptoms Debi had were** fatigue, weight loss, and a severe, persistent cough.

   Question 2

   - **The treatment to cure TB is** a combination of several antibiotics. Debi named standard drugs used for TB such as isoniazid and streptomycin.
   - **When Debi started the treatment** she initially got better.

The Debi French example reminds students of the major concept of the activity: One explanation for the re-emergence of infectious diseases is resistance of the causative agent to the treatment that once cured infections of that agent. The important public health issue is avoiding inappropriate use of antibiotics as a way to minimize, or at least delay, the evolution of resistant pathogens.

Question 3

- **Debi's health began improving when she started the drug therapy for TB because** the bacteria that caused her tuberculosis were killed (or their growth was inhibited) by the drugs she was taking.

Question 4

- **On Valentine's Day 1994, Debi learned** that her tuberculosis was active again.
- **The drugs Debi took to cure her TB were not working because** the bacteria that caused her TB had become resistant to the drugs.

Question 5

- **Debi had a relapse (developed an active case of TB again), even though her health had improved and she was still taking the drugs to cure TB, because** the initial treatment killed some of the disease-causing bacteria, but those that were resistant survived. They continued to multiply, passing their resistance on to their progeny. As a result, the disease in Debi's lungs returned. But now, the disease-causing bacteria were all resistant to the drugs she was taking and the drugs were no longer able to cure her. Point out to students that this is an example of natural selection: The resistant bacteria survived and passed the genes for resistance on to their progeny, whereas the susceptible bacteria did not survive. Soon all or most of the bacterial population, descendants of the resistant organisms, was resistant.

Question 6

- **Debi was finally cured of TB by** taking other drugs that were still able to kill the tuberculosis bacteria and by surgical removal of the upper third of one lung that had the greatest concentration of bacteria.
- **Debi's warning about infectious diseases like TB is** not to be fooled by little bacteria. In her words, they are "stubborn" and develop ways to survive. A scientist would say that bacteria rapidly evolve resistance to the drugs we use to treat infections caused by those organisms.

7. **Point out to students that while it was appropriate to treat Debi with the antibiotics that are usually effective in treating TB, it is not appropriate to use antibiotics to treat illnesses that are caused by viruses. Elicit an explanation of the dangers of this practice by asking a question such as "Although an antibiotic doesn't help you get over a viral infection, if you didn't know any better you might think it wouldn't do any harm. But you know better. Explain what negative consequences can result from inappropriate use of antibiotics."**

   Students should be able to explain that using antibiotics will select for bacteria that are resistant. Subsequent infections—either in the same person or in someone who is infected by the first person—will be

caused by disease-causing bacteria that are resistant, and successful treatment will be much more difficult or even impossible. This line of logic requires extrapolation of the ideas students developed from their bacterial growth experiment and the Debi French story, so you may need to help them develop their explanation by giving them additional information and asking probing questions such as "What if the antibiotic taken by a person who has a bacterial infection doesn't kill all of the disease-causing bacteria? What can you say about the bacteria that survive?" and "Research experiments have shown that harmless bacteria that become resistant to antibiotics can transfer that resistance to other bacteria, including disease-causing bacteria. How does this help explain why doctors don't want to prescribe antibiotics for viral infections?"

You may want to tell students that the evolution of antibiotic-resistant pathogens is a problem for treating more diseases than TB. For example, many strains of the organism that causes the sexually transmitted disease gonorrhea (*Neisseria gonorrohoeae*) and most strains of a common organism that causes many skin infections (*Staphylococcus aureus*) are now resistant to penicillin. Students consider a proposal to develop a new treatment for multiple-drug-resistant *Staphylococcus aureus* in Activity 5, *Making Hard Decisions*.

This step provides an opportunity to evaluate students' understanding of the evolution of antibiotic resistance and its relevance to personal and public health.

8. Distribute one copy of Master 3.5, *Antibiotic Concerns*, to each team and assign one of the three statements to each team. Explain that each statement describes an example of an inappropriate or potentially inappropriate use of antibiotics. Instruct the teams to develop a brief public service announcement that would persuade the general public not to use antibiotics inappropriately. The announcement should be something that could be read on the radio, featured in a television commercial, or displayed on a public bulletin board. Collect the announcements and read several to the class; display all of them on a bulletin board in the classroom.

Laboratory Preparation for Activity 3

1. *Four weeks before conducting the activity*. Order the following materials from Carolina Biological Supply:

   • *Pseudomonas fluorescens* culture, catalog #AA-15-5255
   • nutrient broth, catalog #AA-78-5360
   • nutrient agar, catalog #AA-78-5300
   • kanamycin, catalog #AA-21-6881

   Allow two weeks for delivery. Carolina Biological Supply will only ship live or perishable materials on Mondays, Tuesdays, and Wednesdays.

2. *Two days before conducting the activity*. Prepare the following additional materials:

   • petri dishes
   • capped test tubes
   • sterile 1-ml pipets
   • pipet pumps or bulbs
   • glass rod spreaders
   • Bunsen burners
   • alcohol (for sterilizing the glass spreaders)
   • facilities for sterilizing and preparing growth media

3. Prepare a stock solution of 25 mg / ml kanamycin in water and filter-sterilize it into a sterile test tube.

4. Prepare nutrient broth medium and nutrient agar plates following the directions on the packages. For medium containing kanamycin, aseptically add 2 ml of the stock kanamycin solution per liter of medium after the medium has cooled (but before the agar solidifies, in the case of plates).

5. Dispense 5-ml aliquots of nutrient broth into sterile, capped test tubes. You will need 2 test tubes of nutrient broth and 1 test tube of nutrient broth containing kanamycin for each team. You will also need 3 nutrient agar plates and 3 nutrient agar plates containing kanamycin for each team. We recommend preparing extras to allow for contamination and errors.

6. Inoculate 1 nutrient broth tube with *P. fluorescens* for each team 2 days before Day 1 of the activity (use a 0.1 ml inoculum). Incubate these cultures at 25°C.

If students are unfamiliar with aseptic technique, you will need to provide that instruction before they begin the experiment. Hands, equipment, and counter tops should be washed with a commercial, microbiological disinfectant, or with household bleach diluted 30-fold with water. You should also identify a place for students to discard their used cultures and explain that you will decontaminate all materials before disposal.

The *P. fluorescens* that is cultured in nutrient broth or on nutrient agar will grow up in 24 hours; however, the cultures in media containing kanamycin will take two or three days. We recommend that, after 24 hours of incubation, you refrigerate students' cultures in media without kanamycin (broth culture A and plates 1, 3, and 5). This will prevent overgrown cultures that may obscure the results.

All cultures should be decontaminated when students have completed their work. Used cultures should be placed in an autoclave at 1 atmosphere pressure for 15 minutes to kill bacteria. Plastic petri dishes should be placed in heat-resistant plastic bags prior to autoclaving because the dishes will melt and leak. A kitchen pressure cooker can also be used to kill bacterial cultures.

Bacterial Growth Experiment

Pseudomonas fluorescens, the bacteria used in the laboratory exercise you will begin soon, does not cause disease in healthy people. However, people who have weakened immune systems should not have contact with most microorganisms or with people who handle those organisms. Your immune system may be weakened if you are undergoing antibiotic therapy, if you are taking immunosuppressive drugs or drugs for cancer treatment, or if you have AIDS or are HIV-positive. If you have a weakened immune system for these or any other reasons, let your teacher know and he or she will provide you with an alternative experience that is safer for you.

Follow the directions below to test the hypothesis using the bacterial species *Pseudomonas fluorescens* and the antibiotic kanamycin. The flow chart on the last page provides an overview of the experiment.

Hypothesis:

DAY 1

1. Collect the following materials from your teacher:

   1 test tube culture of *P. fluorescens* (the parental culture)Ä
   1 test tube containing nutrient brothÄ
   1 test tube containing nutrient broth with kanamycinÄ
   1 nutrient agar plateÄ
   1 nutrient agar plate with kanamycinÄ

   You will need the following materials at your laboratory station: 4 sterile 1-milliliter pipets, pipet pumpÄ or bulb, container with disinfectant for disposing of used pipets, Bunsen burner, grease pencil for labelingÄ, and beaker of alcohol with a bent glass rod spreader.Ä

2. For your safety and the success of your experiment, you must use aseptic techniques when handling bacterial cultures. You must also discard used cultures safely. Your teacher will explain and demonstrate aseptic techniques and indicate where you should discard your used cultures (with caps and lids in place). Your teacher will decontaminate all of the cultures before disposal.

   Swirl the *P. fluorescens* culture gently to distribute the bacterial cells evenly. Then follow your teacher's instructions for maintaining sterile conditions while transferring 0.1 milliliter from the culture into the test tube of nutrient broth and into the test tube of nutrient broth with kanamycin. Label the first test tube "A" and the second test tube "B."

3. Swirl the *P. fluorescens* culture again and follow your teacher's instructions to deposit 0.1 milliliter from the culture on each of the nutrient agar plates. Use a sterile, bent glass rod to spread the culture evenly over the surface of the plates. Label the nutrient agar plate "1" and the nutrient agar plate with kanamycin "2."

4. After the culture has soaked into the plates (about 5 to 10 minutes), invert the plates and incubate them and the two broth cultures at 25°C for three days.

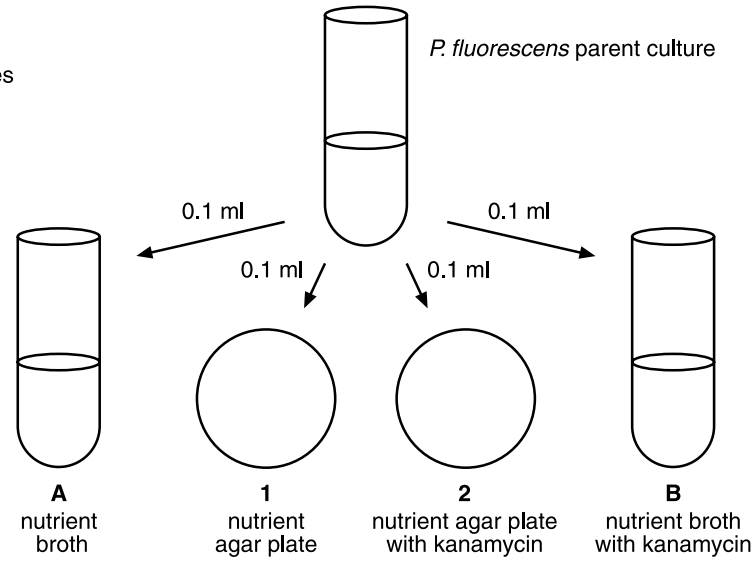
DAY 2 (3 days later)

5. Retrieve the broth cultures (A and B) from the first session and collect 2 new nutrient agar plates and 2 nutrient agar plates with kanamycin. Check that you have 4 sterile 1-milliliter plates, pipet pump or bulb, pipet disposal container, Bunsen burner, and alcohol with a bent glass rod spreader.
6. Swirl culture A gently and follow the procedure in Step 3 to prepare two plates, one nutrient agar plate and one nutrient agar plate with kanamycin. Label the first plate "3" and the second plate "4."
7. Swirl culture B gently and repeat Step 6 using samples from this culture. Label the nutrient agar plate "5" and the nutrient agar plate with kanamycin "6."
8. After the culture has soaked into the plates, invert them and incubate them at 25°C for two or three days. Dispose of the A and B cultures as your teacher directs.

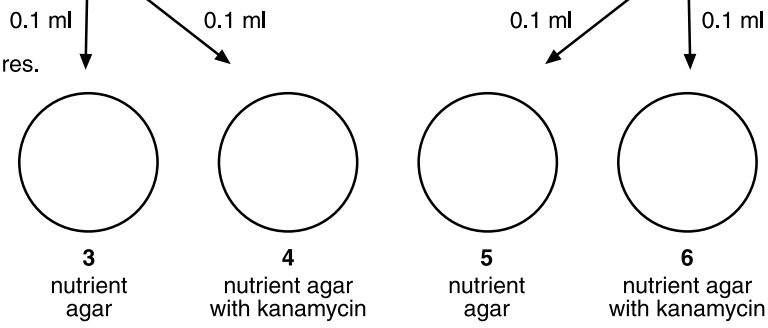
DAY 3 (2–3 days later)

9. Collect all six plates and draw the amount of bacterial growth on each plate on the flow chart.

Day 1
Steps 1 to 4:
Prepare 2 broth cultures
and 2 plate cultures.



Day 2
Steps 5 to 8:
Prepare 4 plate cultures.



Day 3
Step 9: Collect plates and record results above.

Discussion Questions for the Bacterial Growth Experiment

Refer to the results from your bacterial growth experiment as you answer the following questions.

1. Compare the bacterial growth on the two plates from the parental culture (Plates 1 and 2). Which has more growth? Explain why. How do you explain the presence of bacteria on the plate containing kanamycin?

2. Compare the growth on Plates 3 and 4, which you prepared from culture A (without kanamycin). How does the growth on the plates with and without kanamycin appear? What does this tell you about the bacteria grown in culture A?

3. Compare the growth on Plates 5 and 6, which you prepared from culture B (with kanamycin). How does the growth on the plates with and without kanamycin appear? What does this tell you about the bacteria grown in culture B?

4. Compare the growth of cultures A and B on Plates 4 and 6 (with kanamycin). Explain how culture B could have so many more resistant bacteria than culture A, even though they both came from the same parental culture.

5. How do you explain the presence of some resistant bacteria in the parental culture and culture A?

Debi's Story

Read the following transcript of an interview conducted in 1999 with Debi French.

The Diagnosis

My name is Debi French, and I'm 23. The winter of 1993, when I had chronic bronchitis, as I had most of my life, I was not getting any better from the medical therapy. So I went to the doctor and said, "Fix me. There's something wrong."

He did chest X-rays, and that's when we found out I had tuberculosis.

I was coughing. I was extremely exhausted; I fell asleep in almost every class I had every day. I lost nearly 50 pounds. Those were the main symptoms—excessive coughing to the point where, the day I went to the doctor's office, I coughed till I puked.

We did the chest X-rays, and the doctor reviewed them and then had another doctor give a second opinion. Then he came in and told me and my mom . . . And the first thing he said was, "Well, you don't have to go to school." And the first words out of my mouth were, "But I have a parade on Saturday I have to march in."

To say the least, I was not thrilled. My mom was relieved because in her mind it was something curable.

At the time, the only thing I knew about tuberculosis was that people had died from it. And far be it from me to allow myself to die from a little bacteria.

It's not every day that your typical middle-class white girl, living in suburbia, gets a disease like this. Somebody in one of my classes had an active case and continued to go to school, where it spread like wildfire. By the time the testing was complete, they revealed that there were 12 active cases of tuberculosis and 350 positive skin tests showing exposure. So in a small school of about 1,200 people, that's nearly a quarter of the population.

The Initial Treatment

At first, I was on four different medications. After six weeks or so, it seemed like they had done their job. My sputum tests came back negative, so I wasn't active any more. But I would still have to continue drug therapy for about a year.

It worked for a while . . .

The Treatment Fails

During my senior year—February 14, 1994—I'll never forget—my doctor called me and said that the tests that they had been doing to see if I could get off my medication came back positive. I had an active case all over again.

I spent two weeks in UCLA Medical Center, which included my 18th birthday. After two weeks of being there, my parents decided that because I wasn't getting any better, there was no reason to put me and them and the rest of the family through the torture of my having to stay in the hospital, when, aside from the fact I had a communicable disease, I was normal.

So they let me go home, and I was home for about six weeks. Still, I wasn't getting any better, even on new medications. After six weeks, the health department basically told my mom that if they didn't take me to this hospital in Colorado, I was going to die.

A Happy Ending

So I went to Colorado. We had to get a private plane to take us, because when you're contagious, you can't just hop on a commercial airline. The day we were supposed to leave, the plane company—the pilot called and canceled. He backed out. He was afraid for his health, which is understandable, but, nonetheless, it hurt.

Two days later, we got another plane (another pilot) and took off for Denver. It was a nice change of pace. The staff at the hospital knew what was going on and knew how to help me and help my family get better. It was incredible—they saved my life. Between them and my attitude—that's why I'm still here. I ended up losing a third of my right lung—the upper third. I have a lovely scar across my back and I left the hospital with a tube in my chest.

I could have come out of this and still had my right lung, but the largest collection of bacteria was in my right upper lung. It was [a mass] about the size of a golf ball. And they decided that for the best chance of eradicating it completely from my body, it was just safer and easier to take it out. Otherwise, I could still be on medication and that stuff is nasty—really nasty. You really don't want it. Trust me.

Don't be fooled that things like this are of the past, because they have a way of resurging. Bacteria are stubborn.

Debi's Story: Explaining What Happened

Follow the steps below to explain what happened to Debi French.

1. Read *The Diagnosis* to learn about Debi's initial diagnosis. Summarize what you learned by completing the following sentences:

   Debi contracted tuberculosis (TB) from

   The symptoms Debi had were

2. Read *The Initial Treatment* to learn about the treatment prescribed by her doctor and its outcome. Summarize what you learned by completing the following sentences:

   The treatment to cure TB is

   When Debi started the treatment

3. Review the results and conclusions you drew from Plates 1–4 of your bacterial growth experiment. Put together those conclusions with the observations from the first two parts of *Debi's Story* and complete the following sentence:

   Debi's health began improving when she started the drug therapy for TB because

4. Read *The Treatment Fails* to learn what happened to Debi next. Summarize what you learned by completing the following sentences:

   On Valentine's Day 1994, Debi learned

   The drugs Debi took to cure her TB were not working because

5. Review the results and conclusions from Plates 5 and 6 of your bacterial growth experiment. Put together those results and Debi's experience to complete the following sentence:

   Debi had a relapse (developed an active case of TB again), even though her health had improved and she was still taking the drugs to cure TB, because

6. Read *A Happy Ending* to learn what finally happened to Debi. Summarize what you learned by completing the following sentences:

   Debi was finally cured of TB by

   Debi's warning about infectious diseases like TB is

Antibiotic Concerns

Each of these statements describes a potentially inappropriate use of antibiotics. How would you persuade people to eliminate unnecessary use of antibiotics in these cases?

Statement 1

In response to pressure from patients to "give me something," some doctors prescribe antibiotics before they know whether a patient's illness is caused by a virus or a bacteria.

Statement 2

Antibiotics are widely used in livestock feed to improve the growth of animals.

Statement 3

A popular marketing strategy for some products intended for healthy people (for example, hand soaps and children's toys) is to include antibacterial drugs in the products.